NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Renewable Energy: American and Global Progress

World Affairs Council of Northern California Peninsula Chapter

Dr. Dan E. Arvizu, Laboratory Director

January 7, 2015

Energy Market Dynamics

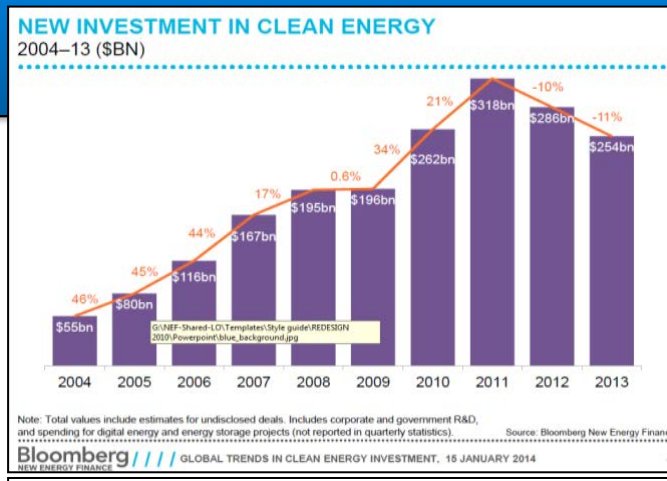
Global renewable industry growing, but faces challenges

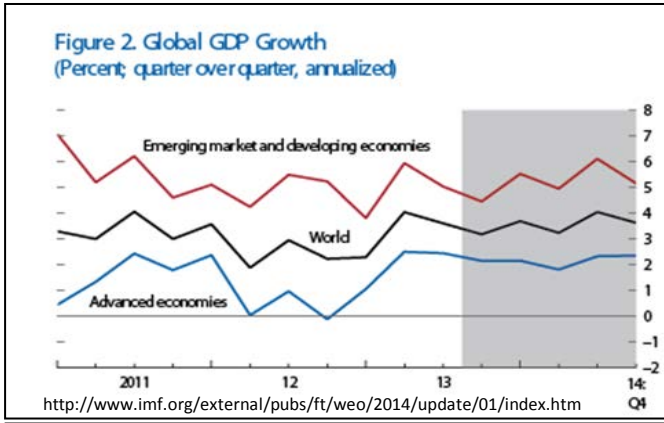
Public policy evolving—mostly local

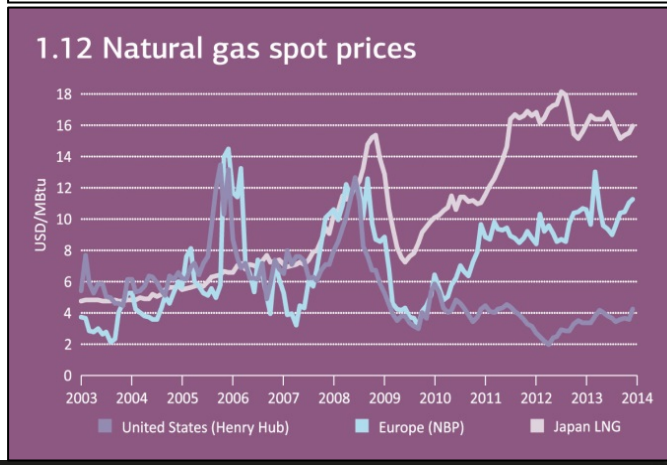
Continued global financial instability

Unconventional gas a growing focus with geographic disparities

Infrastructure investments will be made, must focus on flexibility







Rev 1/5/2015

A Profound Transformation is Required

Today's Unsustainable Energy System

- Limited fuel diversity
- Subject to price volatility
- Inefficient and rigid
- Significant carbon emissions
- Delivery systems vulnerable
- Aging infrastructure

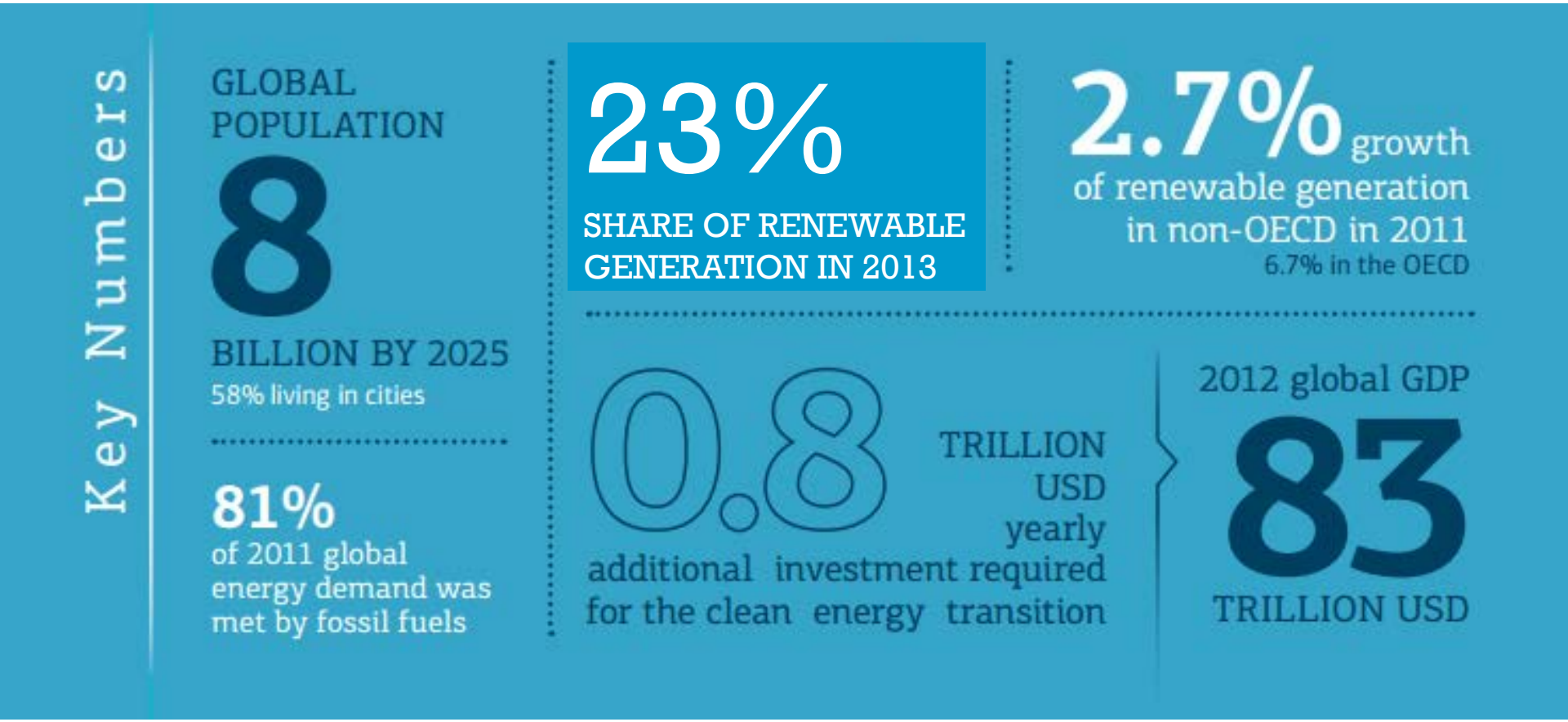
Future Sustainable Energy System

- Diverse supply options
- Affordable, stable and reliable
- Efficient and flexible
- Carbon neutral
- Secure and resilient
- Engine for innovation

TRANSFORMATION

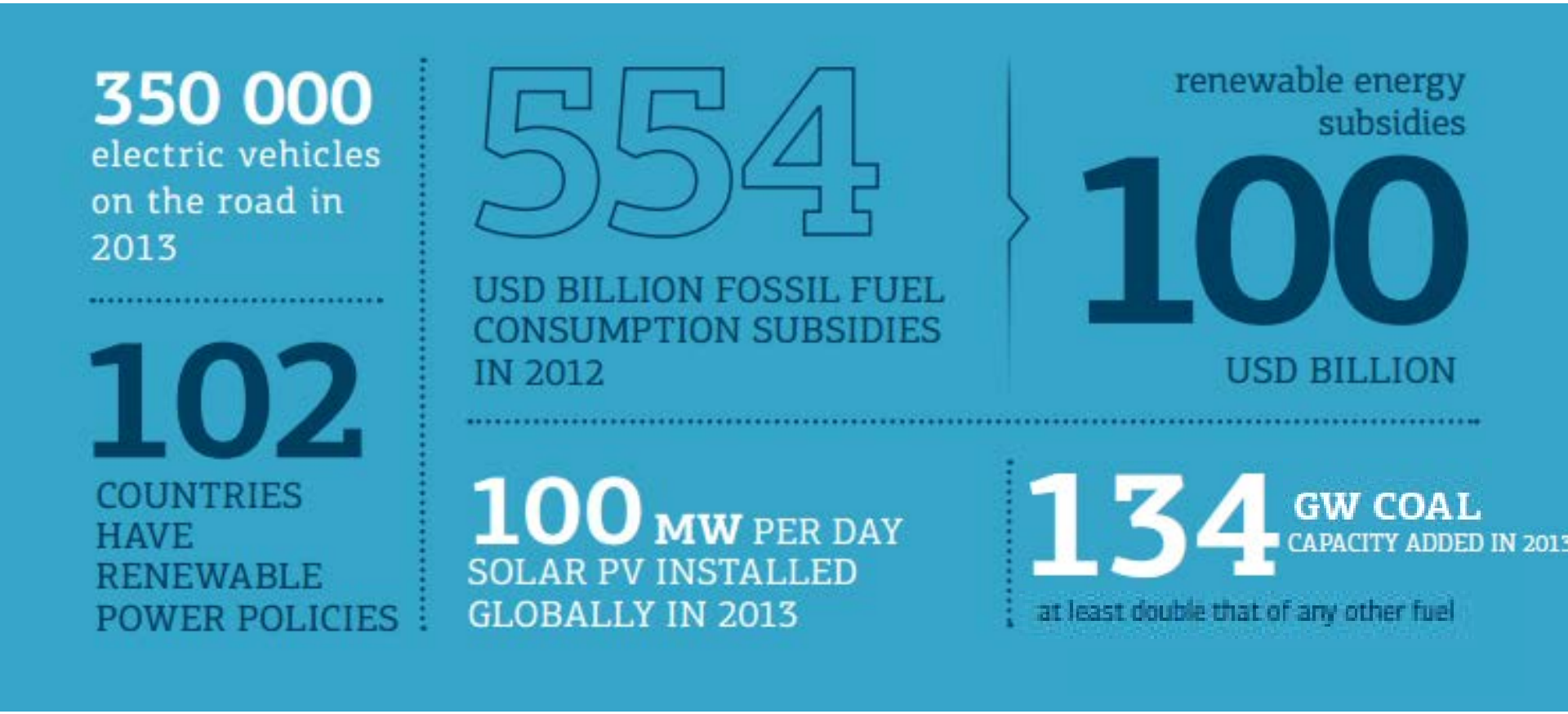
1/5/2015

Global Context



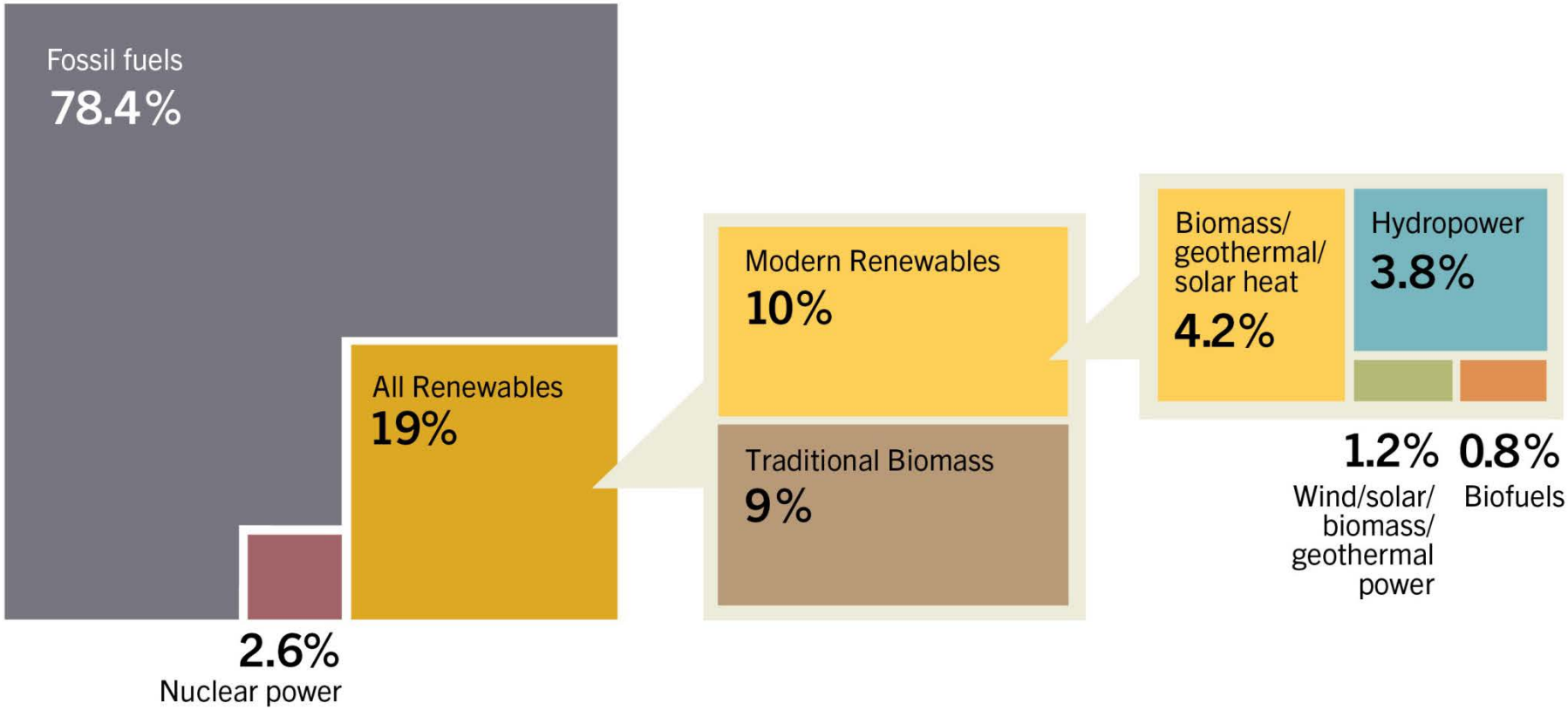
Source: IEA http://www.iea.org/publications/freepublications/publication/Tracking_clean_energy_progress_2014.pdf
NREL 2013 Data Book

Global Context



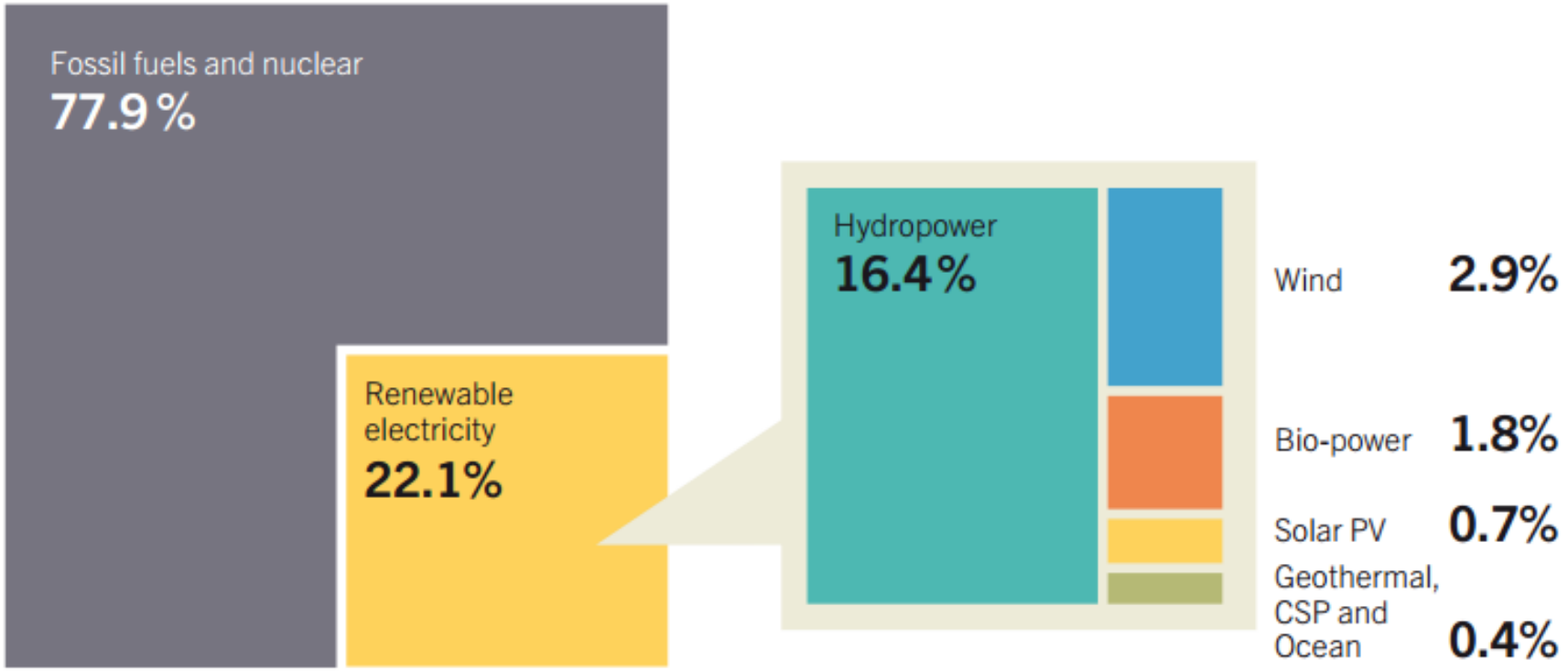
Source: IEA http://www.iea.org/publications/freepublications/publication/Tracking_clean_energy_progress_2014.pdf

Estimated Renewable Energy Share of Global Final Energy Consumption (year end 2012)



Source: *REN21 Global Status Report 2014*
http://www.ren21.net/portals/0/documents/resources/gsr/2014/gsr2014_full%20report_low%20res.pdf

Estimated Renewable Energy Share of Global Electricity Production (year end 2013)



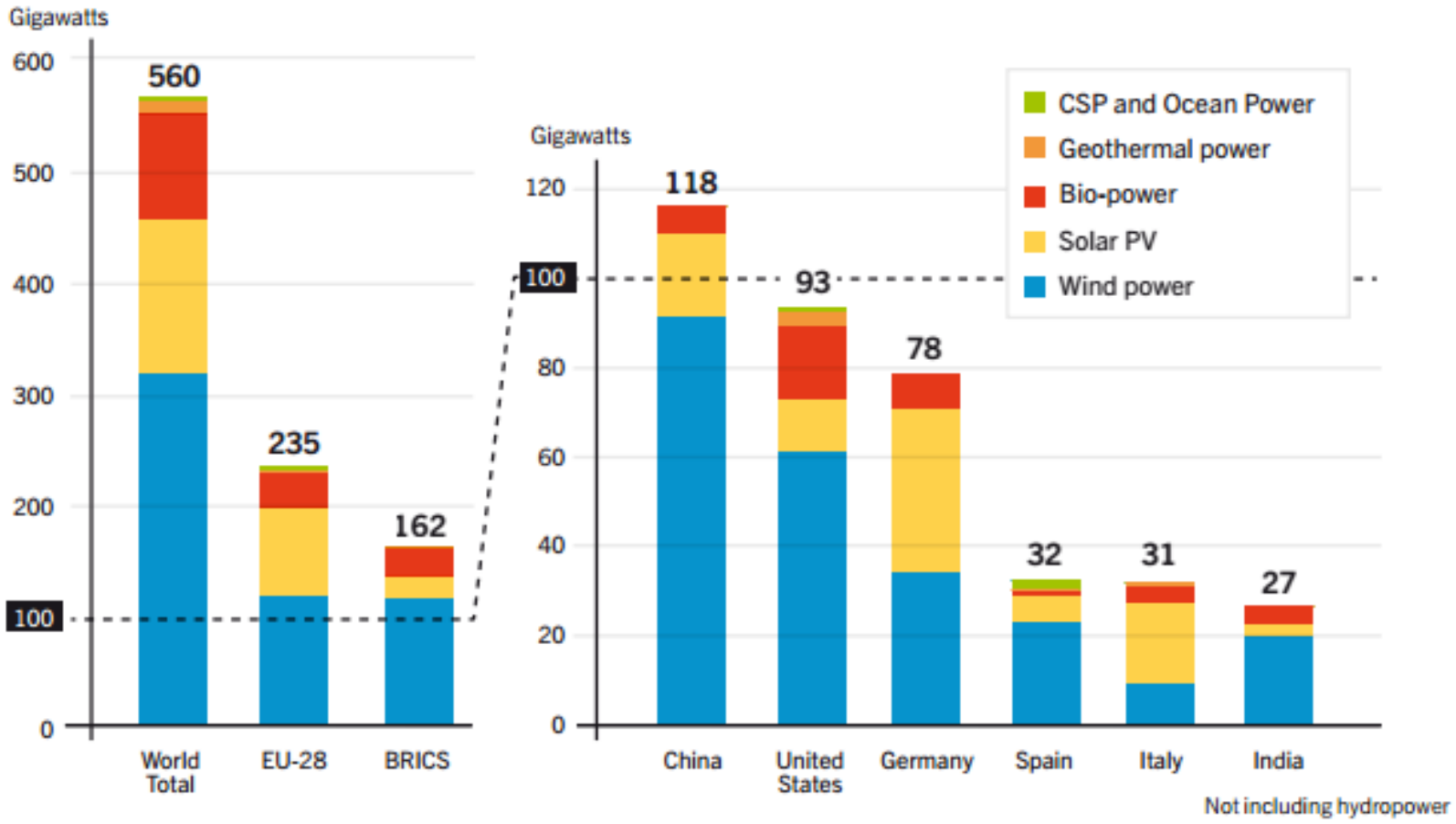
Based on renewable generating capacity in operation end-2013. Data do not add up due to rounding.

i - The GSR 2013 reported a global total of 990 GW of hydropower capacity at the end of 2012; this figure has been revised downward due to better data availability. This adjustment also affects the global figure for total renewable power capacity. In addition, global hydropower data and thus total renewable energy statistics in this report reflect an effort to remove capacity of pure pumped storage from the totals. For more information, see Methodological Notes, page 142.

Source: *REN21 Global Status Report 2014*
http://www.ren21.net/portals/0/documents/resources/gsr/2014/gsr2014_full%20report_low%20res.pdf

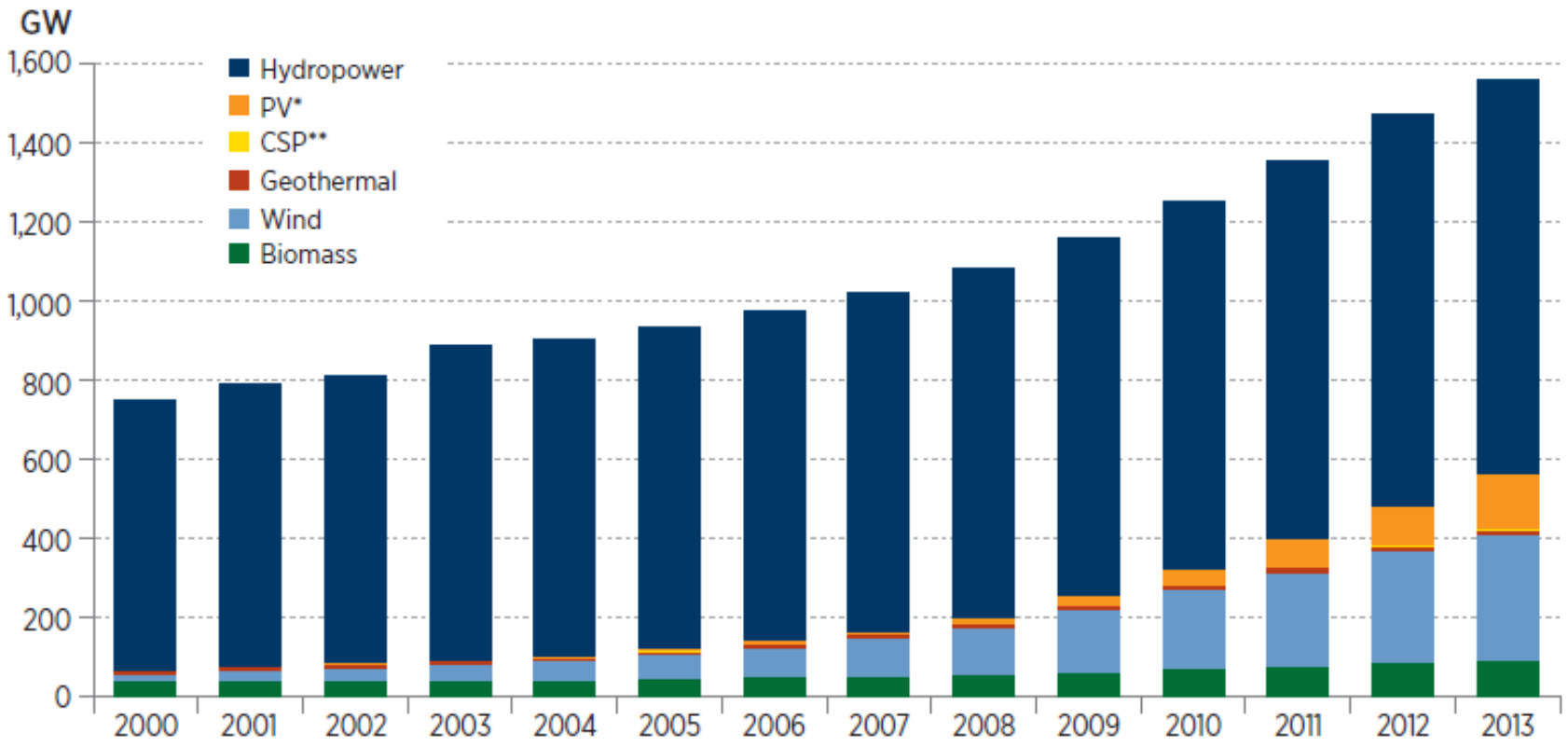
Worldwide Renewable Power Capacity

Figure 4. Renewable Power Capacities in World, EU-28, BRICS, and Top Six Countries, 2013



Source REN21 ***Renewables 2014 Status Report***
http://www.ren21.net/Portals/0/documents/Resources/GSR/2014/GSR2014_full%20report_low%20res.pdf

Global Renewable Electricity Capacity



*Grid-connected only

**CSP includes Concentrated Photovoltaic (CPV)

Source: Renewable Energy Policy Network for the 21st Century (REN21)

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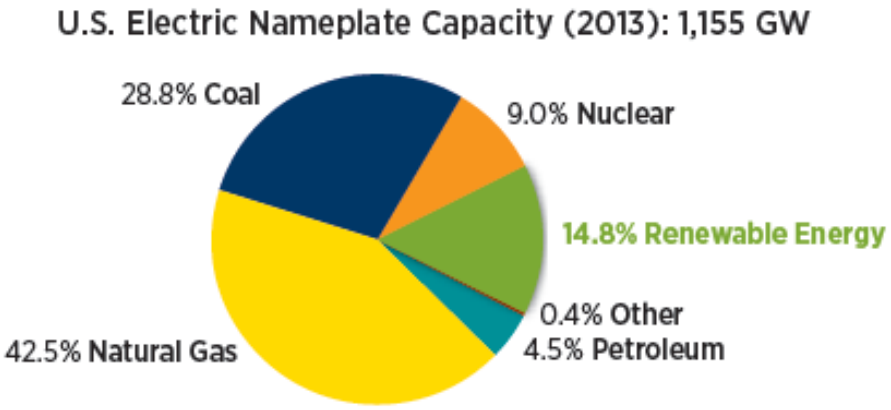
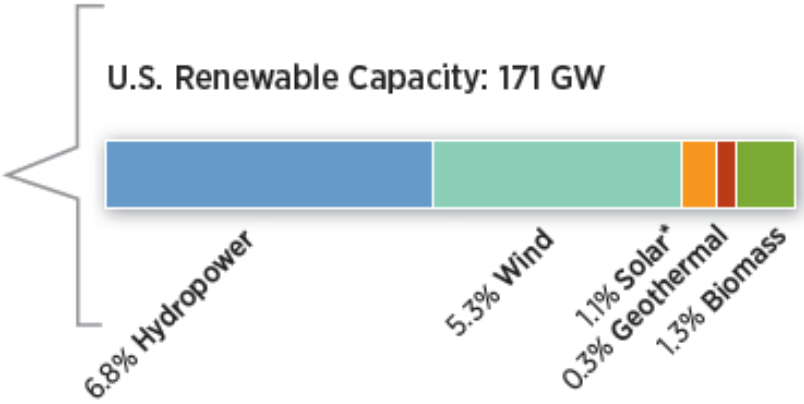
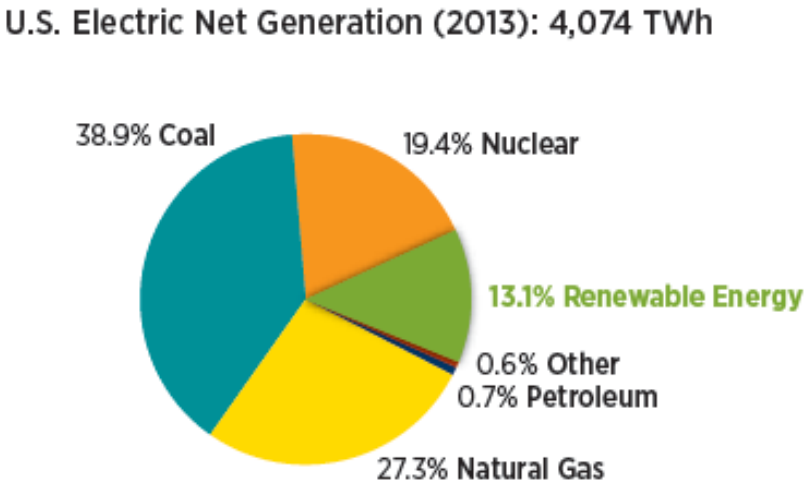
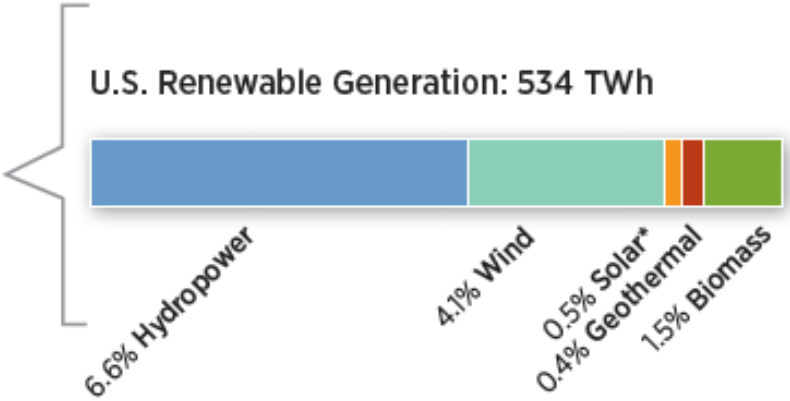
Source: NREL 2013 Data Book

U.S. Electricity Nameplate Capacity and Generation (2013)









Sources: EIA, Larry Sherwood/Interstate Renewable Energy Council (IREC)

Other includes pumped storage, batteries, chemicals, hydrogen, pitch, purchased steam, sulfur, tire-derived fuels, and miscellaneous technologies.

*Grid-connected only

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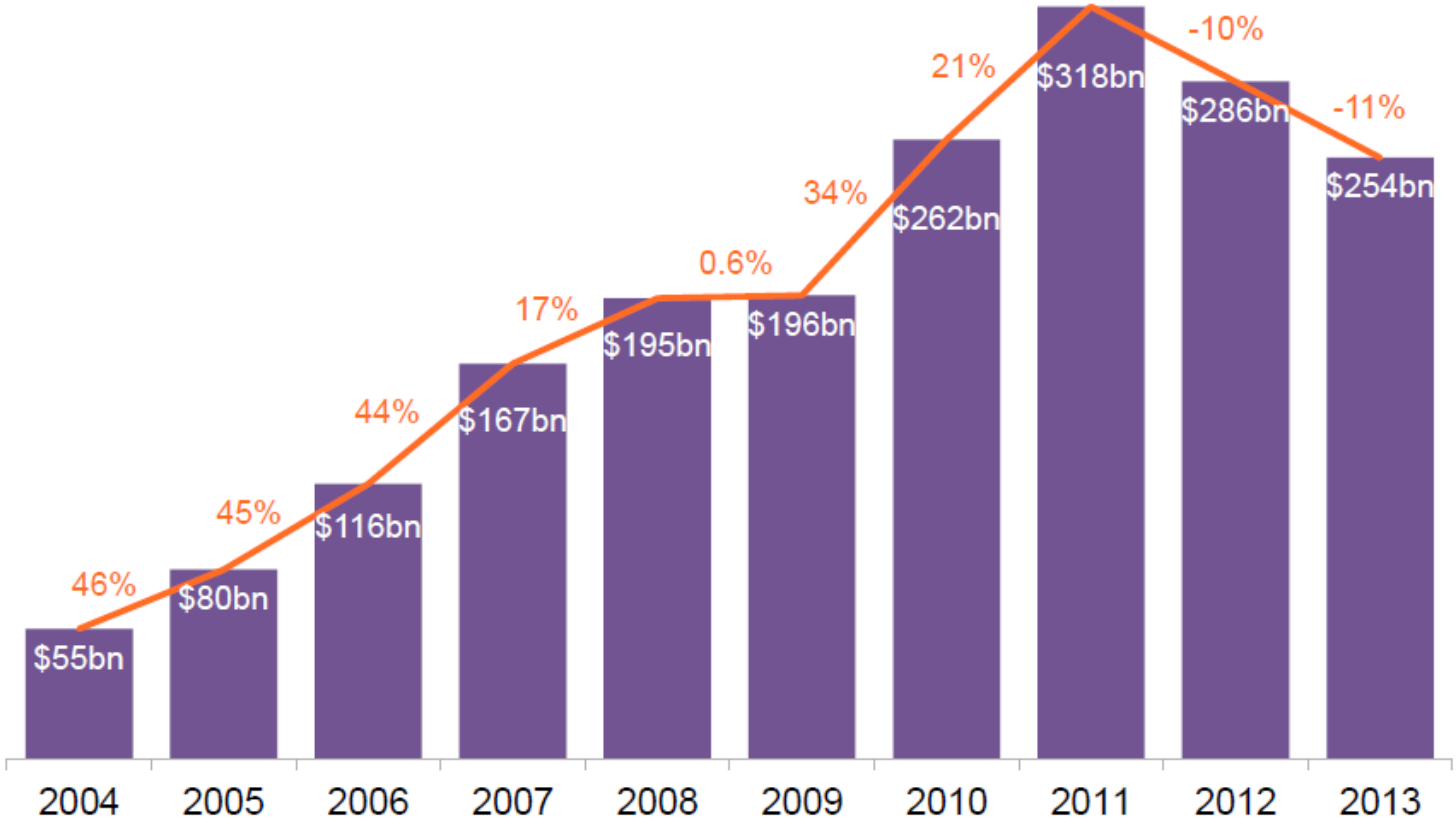
Source: NREL 2013 Data Book

Global New Investment in Renewables

NEW INVESTMENT IN CLEAN ENERGY

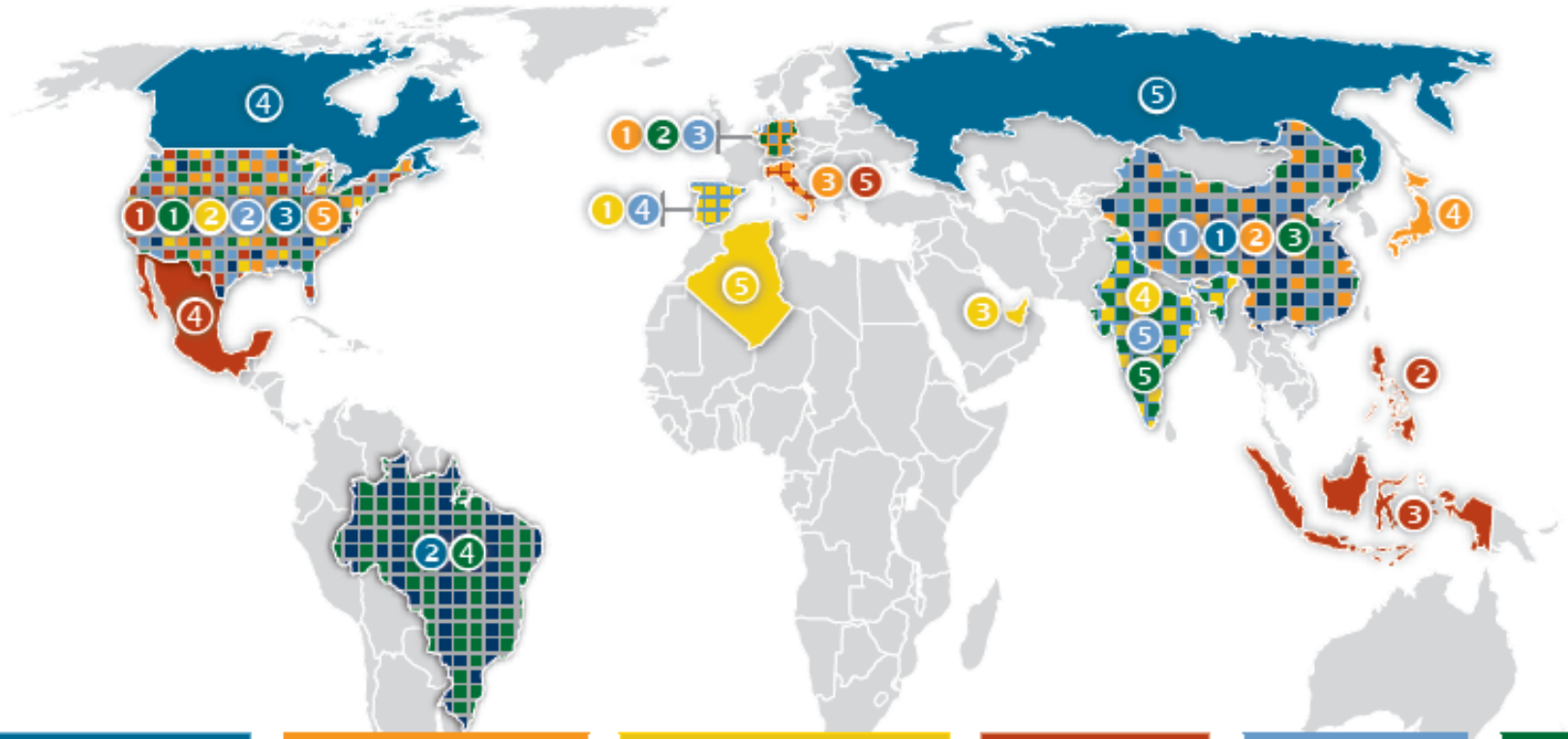
2004–13 ($BN)



Note: Total values include estimates for undisclosed deals. Includes corporate and government R&D, and spending for digital energy and energy storage projects (not reported in quarterly statistics).

Source: Bloomberg New Energy Finance

Top Countries with Installed Renewable Electricity by Technology (2013)



Hydropower	Solar PV*	CSP	Geothermal	Wind	Biomass
1 China	1 Germany	1 Spain	1 United States	1 China	1 United States
2 Brazil	2 China	2 United States	2 Philippines	2 United States	2 Germany
3 United States	3 Italy	3 United Arab Emirates	3 Indonesia	3 Germany	3 China
4 Canada	4 Japan	4 India	4 Mexico	4 Spain	4 Brazil
5 Russia	5 United States	5 Algeria	5 Italy	5 India	5 India

Sources: REN21

*Grid-connected only

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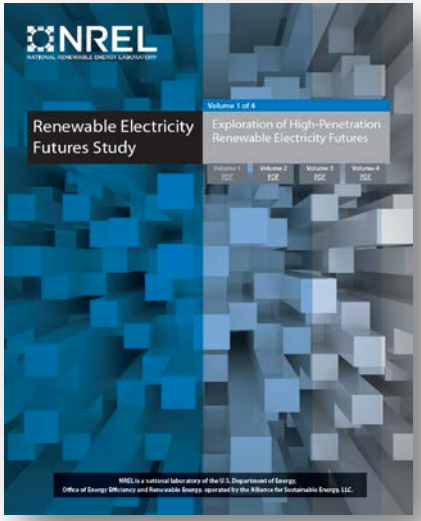
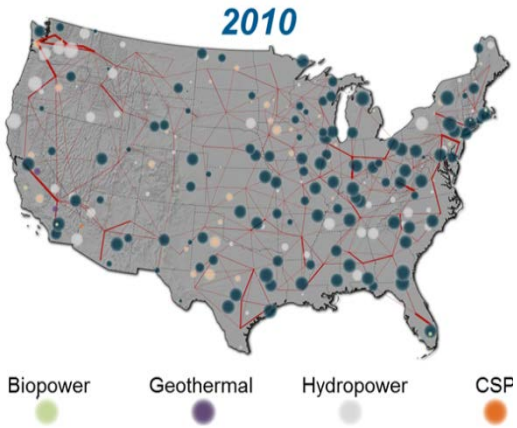
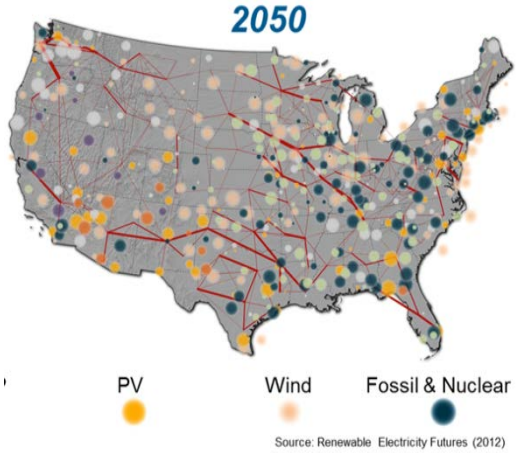
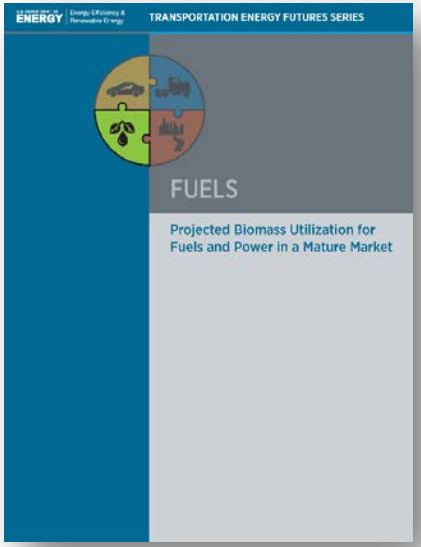
Source: NREL 2013 Data Book

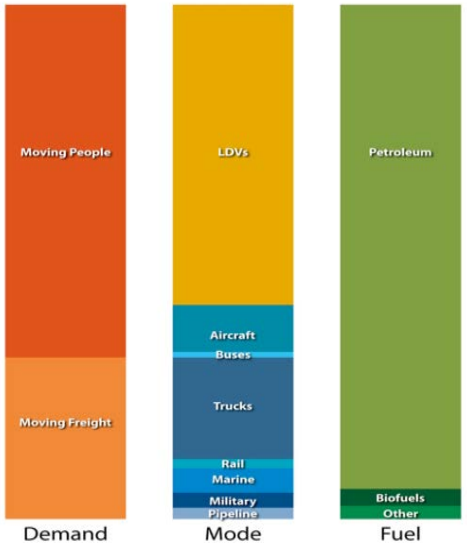
Comprehensive Studies Validate Opportunity for U.S. Renewables

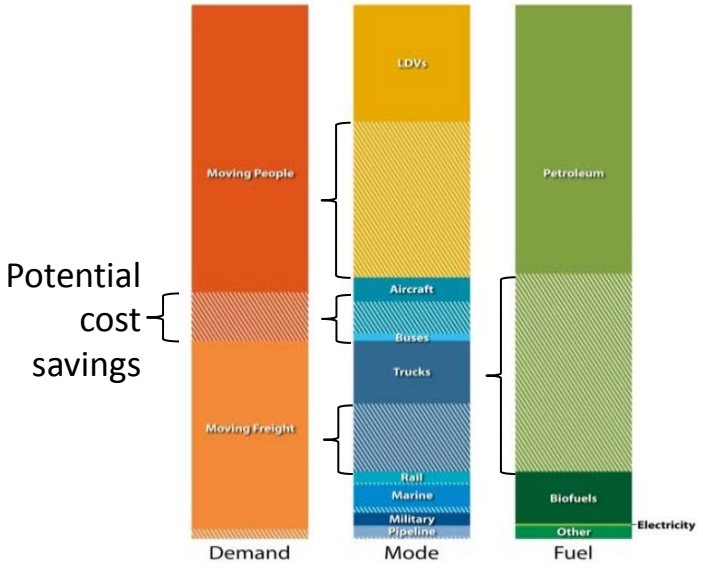




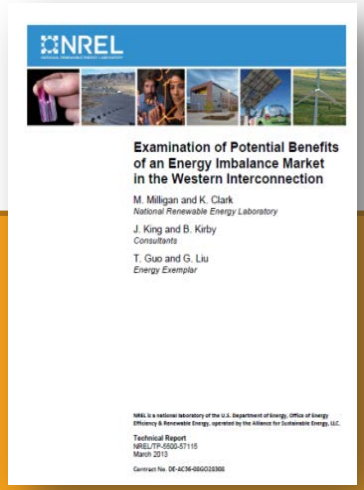


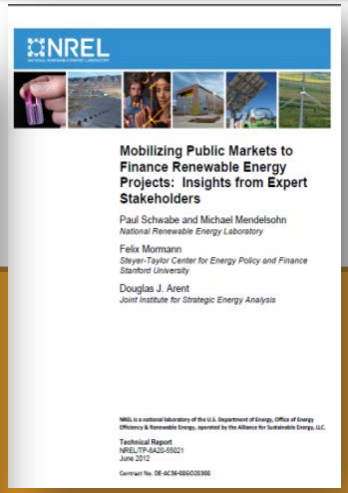


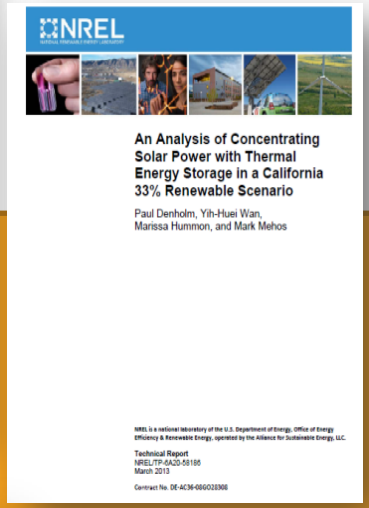


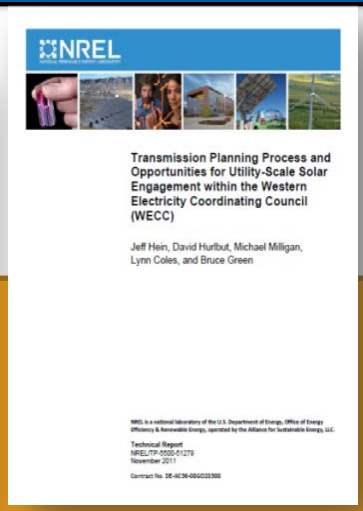


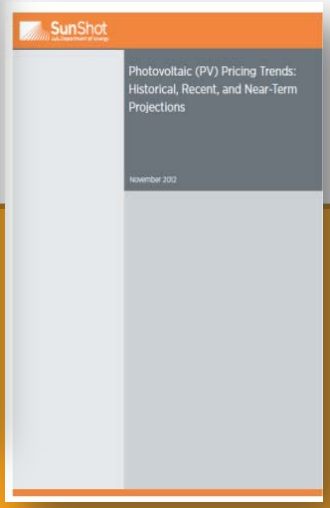
Looking Toward Implementation

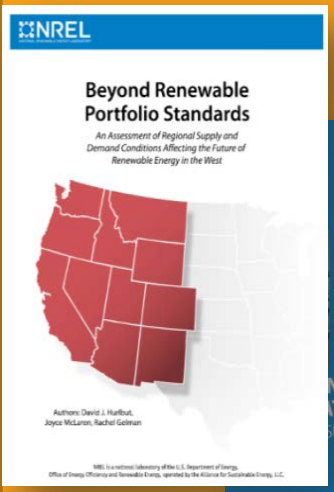


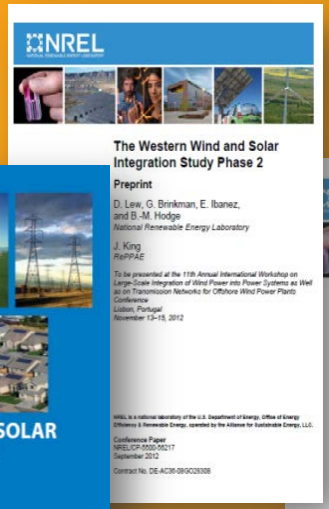


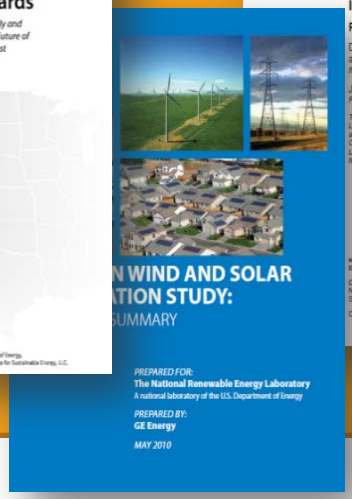












- Benefits of distributed generation
- Economics of technical pathways
- Implications of high penetration renewables
- Value of regional cooperation

Innovation, Integration, and Adoption

Reducing Investment Risk

- Enable basic and applied clean energy technology innovation
- Accelerate technology market introduction and adoption
- Integrate technology at scale
- Encourage collaboration in unique research and testing "partnering" facilities

Mobilizing Capital

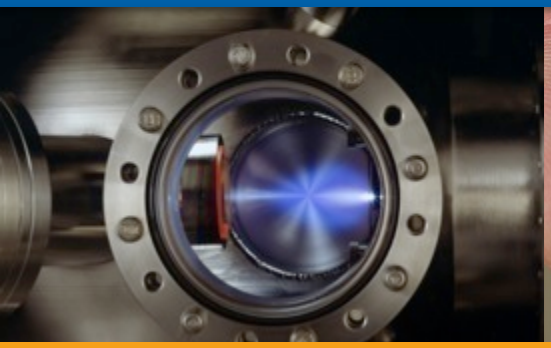
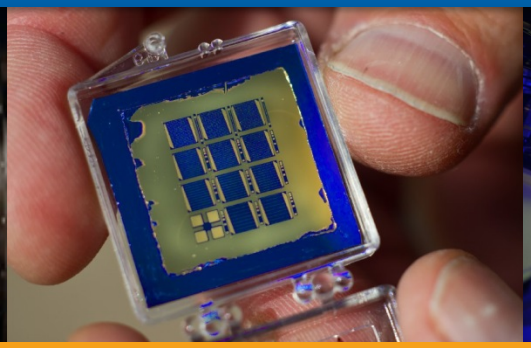
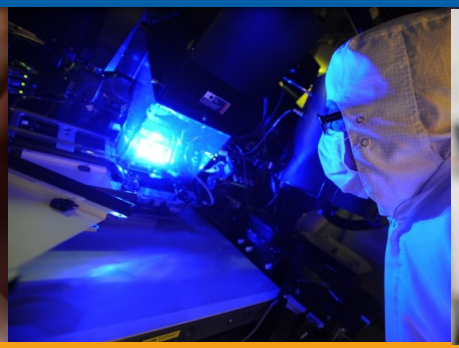
Commercial Partnerships

Technology Innovation

Sustainable
TRANSPORTATION

Renewable
ELECTRICITY GENERATION

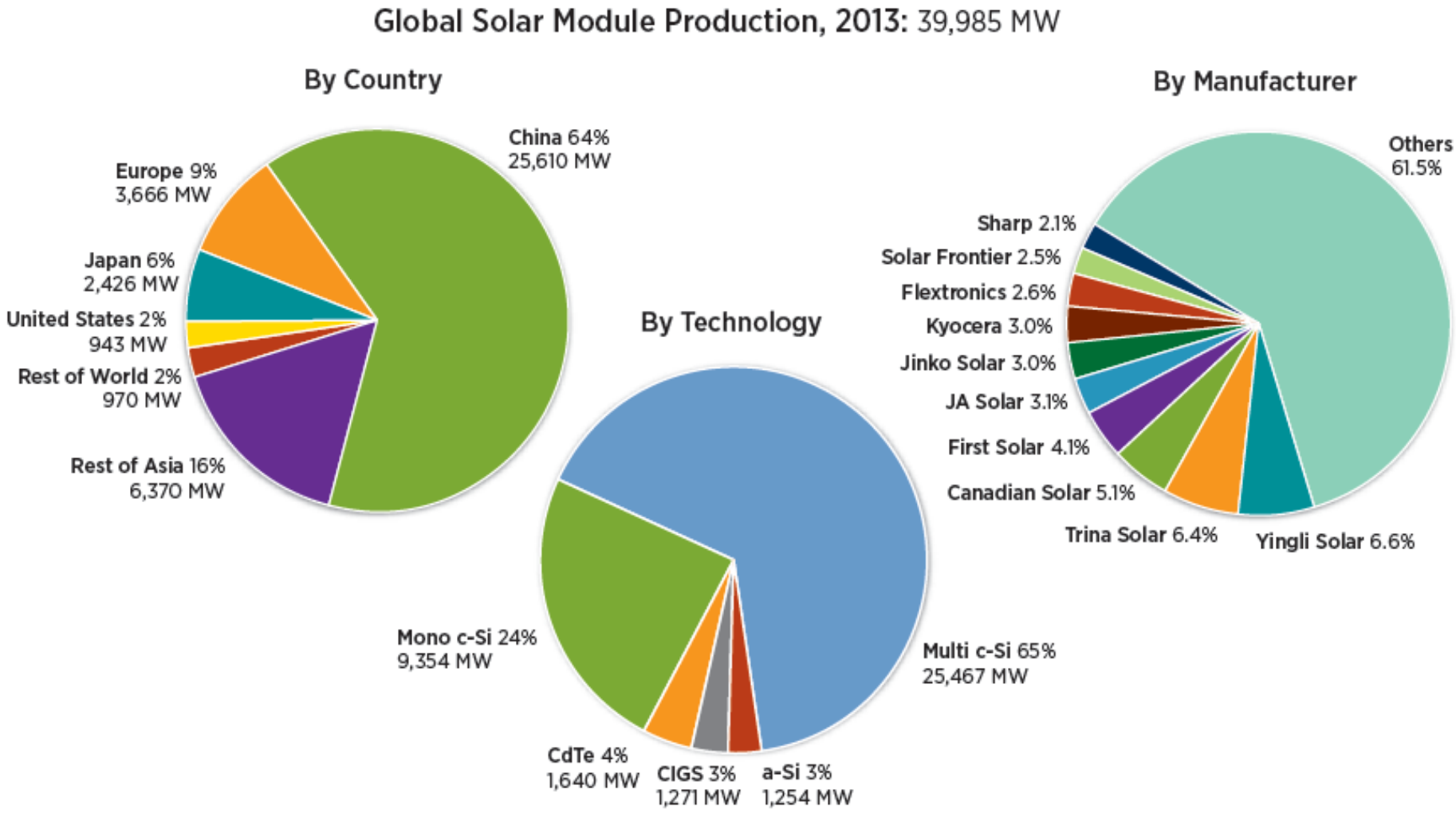
Energy Saving
HOMES, BUILDINGS, & MANUFACTURING


Market Impact

- U.S. Capacity:
  - 12.1 GW
- U.S. Forecast:
  - 40+ GWs in pipeline
- Costs:
  - <$2 to $6/W: *LCOE 7 to 16¢/kWhr
  - <1% of U.S. power generation

Worldwide Photovoltaic Manufacturing (2013)



Source: GTM PV News, May 2014

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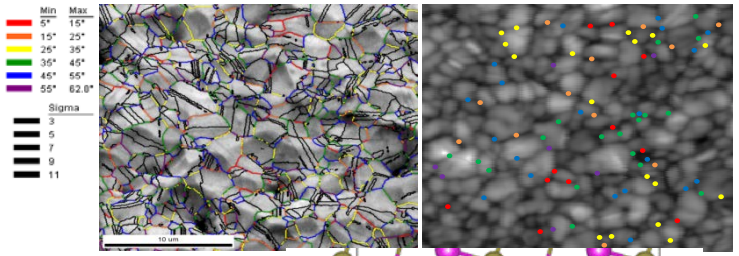
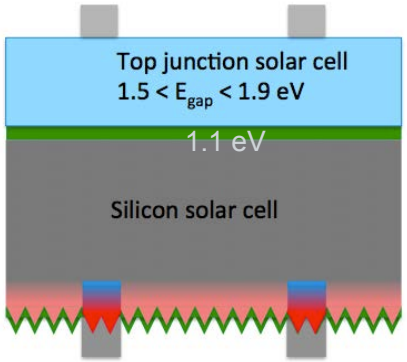
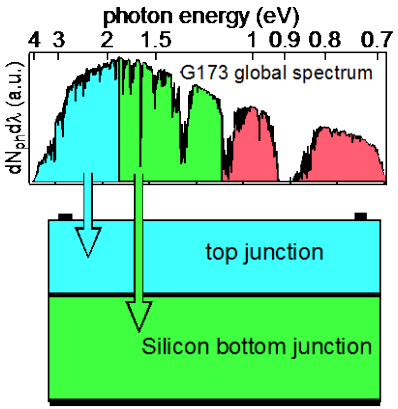
Source: NREL 2013 Data Book

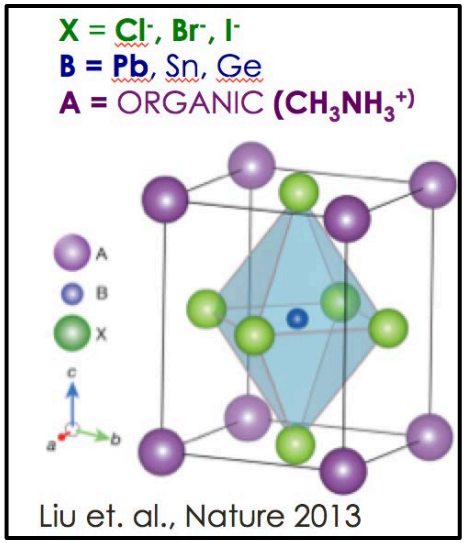
PV Technologies

- High Efficiency Thin Films – Improved carrier lifetime and development of doping techniques will boost commercial module efficiency to 16%.
- Si Tandem Cells – Potential to increase the best cell efficiencies by 10%, to over 30%.
- Low Cost III-V 1J & 2J Cells – Potential to lower III-V growth cost by 1 – 2 orders of magnitude.
- "Kerfless Si" Wafers & Cells – Potential to cut supply chain capital investment by 50% with comparable cell performance.
- Perovskites – Very new polycrystalline thin film technology that has already demonstrated η > 17%.

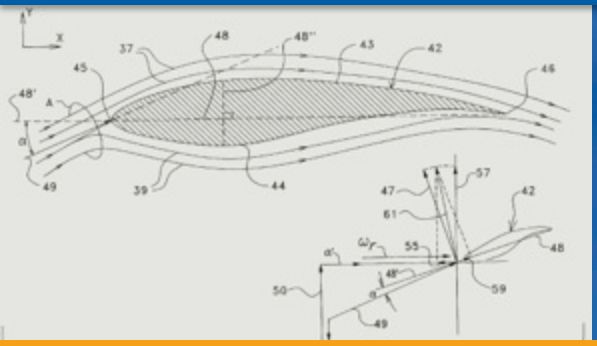








NREL Research: Wind



Market Impact

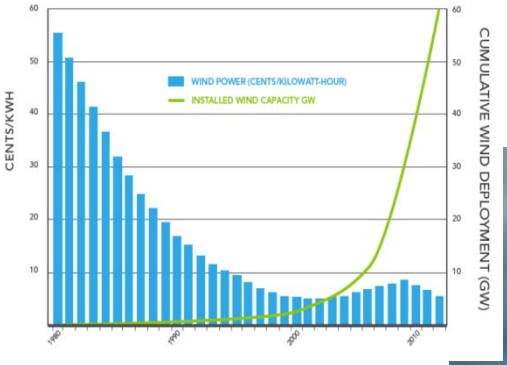
- Costs: 4-7 cents/kWh LCOE*
- Installed capital cost between $1,300 and $1,900/kW depending on region and size
- U.S. ranks 2nd in world for installed wind capacity, equal to nearly 4.5% of total electrical demand
- 62 GW of wind capacity installed

Wind Technologies

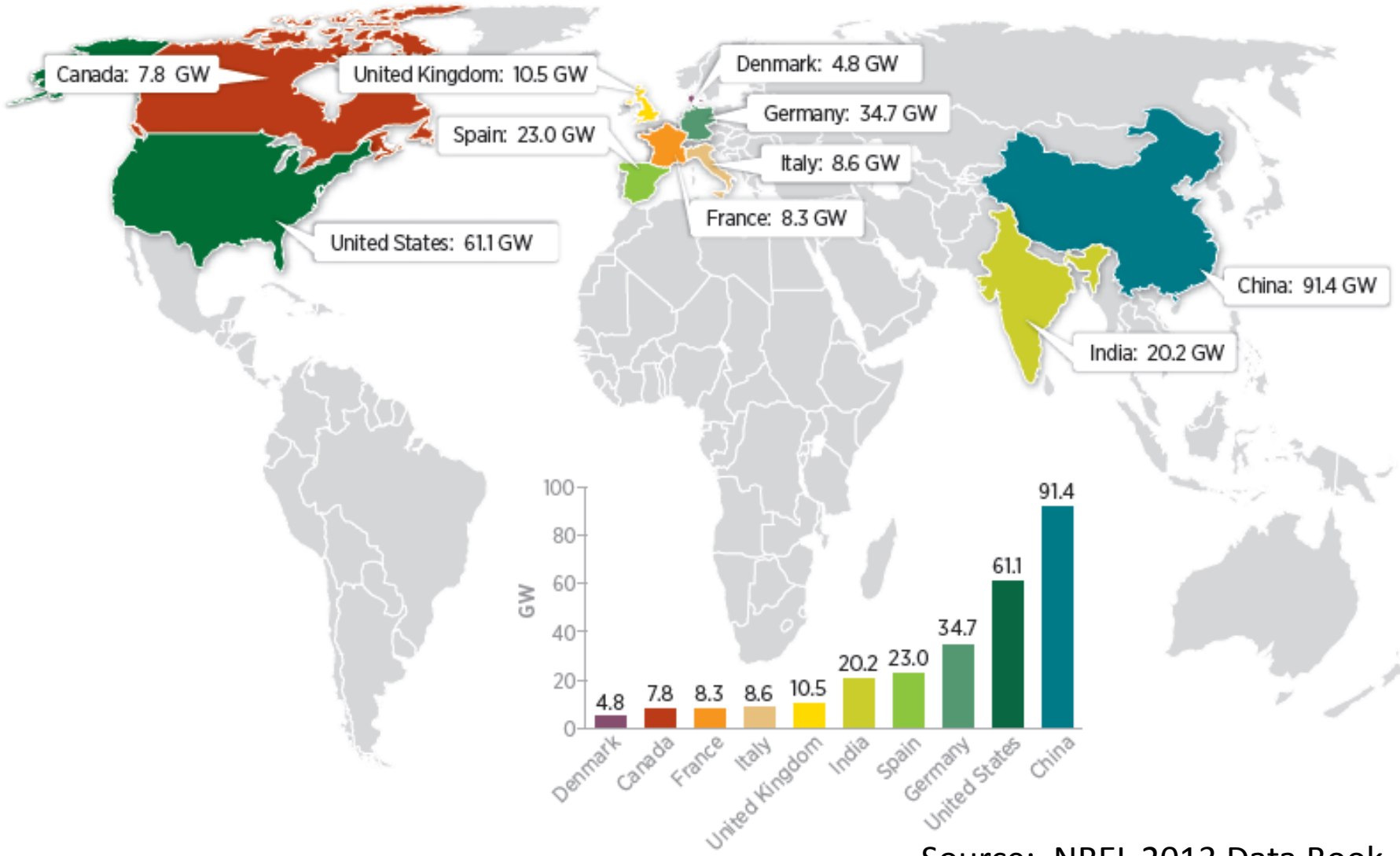
ATMOSPHERE TO ELECTRONS
U.S. DEPARTMENT OF ENERGY

DOE Thrust: Atmosphere to Electrons

- Wind farm system improvements
- Component improvements
  - Modular large components – blades, drivetrains, and tall towers
  - Advanced drivetrain power conversion systems
  - Flexible, ultra-large rotors and systems
  - Active controls for structural load reduction, improved wind plant performance, and grid-friendly operation
  - Floating offshore wind turbines
  - Airborne wind power systems



Cumulative Wind Electricity Capacity (2013) – Top 10 Countries



Sources: LBNL, REN21
Includes offshore wind

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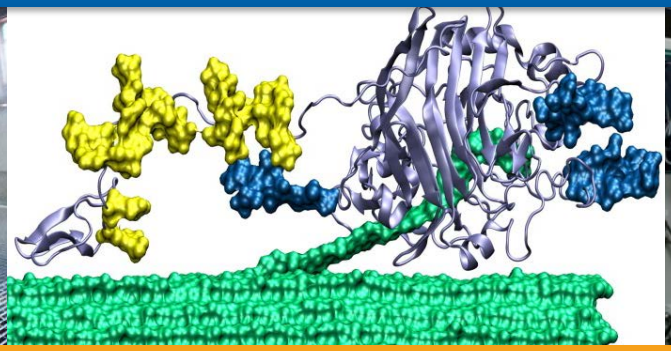
Source: NREL 2013 Data Book

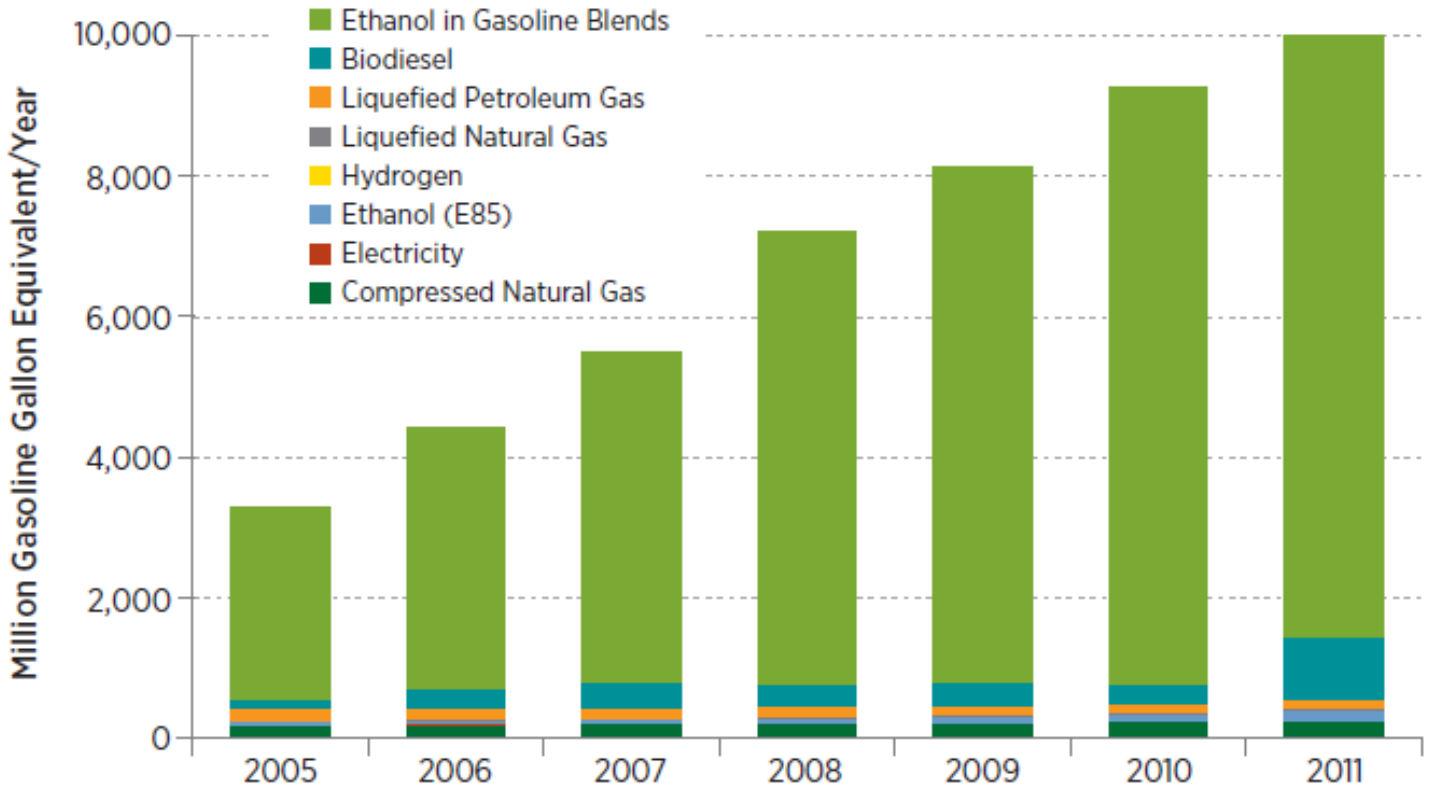
NREL Research: Biofuels

Market Impact

- U.S. produced 13.3 billion gallons of ethanol and 1.34 billion gallons of biodiesel in 2013
- Biorefineries:
  - 211 commercial corn ethanol plants
  - 115 biodiesel refineries
  - 3 commercial cellulosic ethanol plants
- Cellulosic ethanol cost parity with gasoline demonstrated by NREL/EERE at pilot scale in 2012

Consumption of Renewable and Alternative Fuel in the United States



Source: EIA
Data as of April 2013.
2012 and 2013 data were not available at the time of publication.

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Source: NREL 2013 Data Book

NREL Research: Sustainable Transportation




Market Impact

- EVs and PEVs gaining market share
  - Global PEV sales have doubled every year since 2009, to 400,000 in 2014
- Batteries gaining in performance
- Manufacturers exploring vehicle-to-home and vehicle-to-grid

NREL Research: Sustainable Transportation




EV Everywhere; Battery Storage

Fuel Cell Technologies

Vehicle Technologies Battery R&D


FY 2015 Goal: Reduce the cost of a PHEV40 battery to $275/kWh

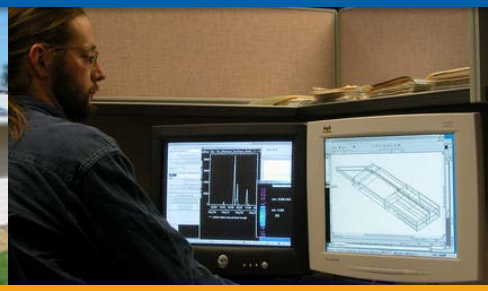
EV Everywhere Grand Challenge

EV Everywhere Blueprint (Jan 2013)

Reducing PEV costs and breaking down the most difficult PEV *EV Everywhere* deployment barriers.

NREL Research: Building Efficiency



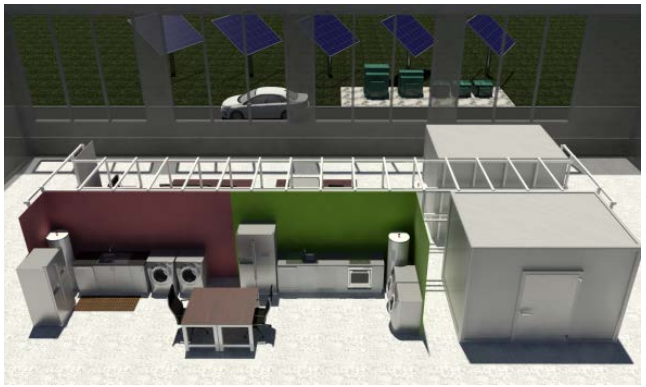
Market Impact

- NREL installed and retrofitted 30,000 high-efficiency rooftop air conditioning units (six times the goal) that will result in saving the Navy 3 trillion BTU of primary energy
- FY14, Xcel Energy estimates they saved over $500,000 in costs by using EDAPT to design new energy-efficient buildings, and are tracking more than 105 new construction projects. As a result, many other utilities are adopting the EDAPT tool.

NREL Research: Building Efficiency




Next-Generation Building Technologies



- Advanced sensors, controls, and feedback mechanisms for buildings (IPOS, Building Agent)
- Using big data to find retrofit opportunities
- Advanced windows and HVAC systems

Electrochromic materials

NREL Research: Energy Systems Integration



Early Impact

- New advanced inverters allow distributed generation to provide grid support
- Smart grid roll outs under ARRA
- IEEE Interconnection Standards
- 45 partners
- ~ $20M level of effort

The New Frontiers: Integration and Scale

- Integration of high-penetration renewables requires enhanced system-wide flexibility
  - Variable supply and variable load
  - Increased distributed resources
  - Enhanced energy imbalance market cooperation
  - Changing roles of consumers, utilities, investors, power providers, vendors, and regulators
- Regional considerations continue to drive progress
- Production scale and supply chain crucial to lower manufacturing costs
- Investment in technology R&D imperative
  - Better monitoring and measurements
  - Advanced analytics processing and control
  - Demand-shifting and load profile shaping techniques
  - Two way power flow control electronics

To achieve a clean energy vision, we must…

Invest in innovation

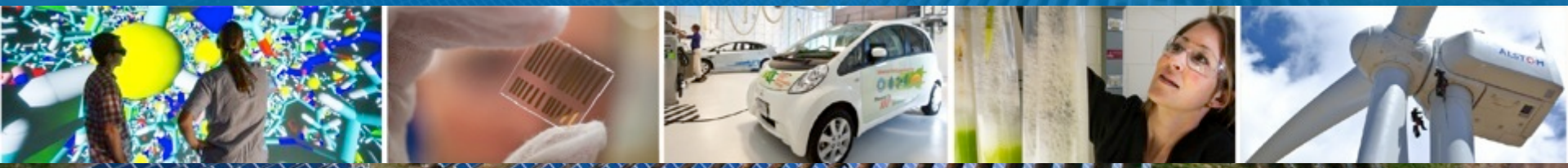
Invent the future we desire

Improve access to capital

Partner on a global scale

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

For more than 35 years, NREL has delivered innovation impact enabling the emergence of the U.S. clean energy industry.



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